

# Coaster Physics

Explore conservation of energy by experimenting with marble roller coasters and pendulums.

**Grade Level:** 6th Grade

**Phenomena:**

What gives objects potential and kinetic energy?

**Objectives:**

- Students will explain the difference between potential and kinetic energy.
- Students will provide an example of conservation of energy.

**Materials:**

- Marbles (1 per group)
- Foam pipe insulation (3-5 ft/ group)
- Protractors
- Tape measures or yard sticks
- Masking tape
- String
- Washers
- Bouncing ball
- Toothpicks

**Appendixes:**

**Time Considerations:**

- Preparation: 45 minutes
- Introduction: 5 minutes
- Activity 1: 15 minutes
- Activity 2: 25 minutes
- Conclusion: Remaining time

**Related Lesson Plans:**



## Next Generation Science Standards

MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

**Science and Engineering Practices (SEP):**

Planning and carrying out investigations.  
Asking questions and defining problems.

**Disciplinary Core Ideas:**

PS2.A: Forces and Motion  
PS2.B: Types of Interactions

**Cross Cutting Concepts:**

Cause and Effect  
Systems and System Models  
Stability and Change

## Excellence in Environmental Education Guidelines

- **Strand 1— Questioning, Analysis and Interpretation:** *A) Questioning*—Learners are able to develop questions that help them learn about the environment and do simple investigations. *B) Designing investigations*—Learners are able to design simple investigations. *C) Collecting information*—Learners are able to locate and collect information about the environment and environmental topics. *G) Drawing conclusions and developing explanations*—Learners can develop simple explanations that address their questions about the environment.

## Background

The term energy is commonly associated with the electricity in our homes and the gasoline we use to power our cars. However energy comes from many more sources than fossil fuels or electric current. Energy plays a role in every aspect of the natural world.

Many types of energy are more difficult to recognize than something like electricity. The molecules that make up

our food or are inside batteries have what is called chemical energy. Heat, light, and sound are also types of energy.

The idea that energy is necessary for motion is widely accepted. People need chemical energy from food; cars need heat energy from burning gasoline. However flowing rivers, rolling rocks, and blowing leaves all have energy as well.

## Doing the Activity

The energy responsible for motion is called kinetic energy. Kinetic energy depends on the mass and velocity of the moving object so even objects moving at the same speed can have different energy.

*(Hyperphysics)*

For example a house cat and a white tailed deer can both run at speeds up to 30mph. Yet even though they can go the same speed the deer weighs much more than the cat so it has more energy.

*(Factmonster)*

It's easy to imagine that all moving things have energy, but even a rock sitting on top of a hill has energy. It has the potential to roll down the hill so the energy that many objects have at rest is called potential energy. Just like kinetic energy, the amount of potential energy an object has depends on how much it weighs. Since it is not moving though, speed gets replaced by gravity and the object's height off the ground. On Earth, gravity is always  $9.8 \text{ m/s}^2$  or  $32 \text{ ft/s}^2$ .

Kinetic and potential energy are always in balance, and it is possible for an object to have both types of energy at the same time. One of the simplest examples is a playground

swing. At the very top of each swing, the swinger has all potential energy. As she comes down, that energy changes until all of the energy is kinetic at the



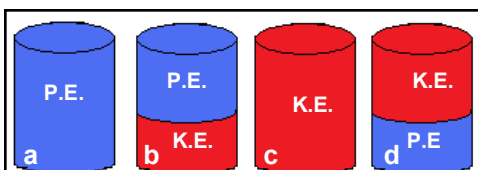
This little girl has only potential energy at the top of her swing. (swing)

very bottom of the swing.

*(Physics.about.com)*

A common way to visualize the changing energy is using a model called energy buckets.

Energy buckets are always "full" but the ratio of kinetic and



Energy buckets showing the changing kinetic and potential energy on a swing where buckets a & c are the very top and very bottom of each swing

potential energy changes.

The sum of potential and kinetic energy is always the same for a particular situation. The only way to change the total amount of energy is to add a new force. The force could come from someone pushing the swing or dragging your feet in the grass. A push adds more kinetic energy but dragging your feet transfers some of the energy to the ground and the

swing slows down.

Roller coasters are a more exciting application of this science. While an electric motor often carries roller coaster trains to the top of the first hill, the rest of the ride is almost



The first hill of the American Eagle is 147 feet tall so riders can coast along 4,650 feet of track without motors or engines. *(Frank Prager, Six Flags)*

always powered by the

## Preparation

potential energy at that tallest point. That's why most roller coasters have the biggest hill first.

Cut foam pipe insulation into 3 to 5 foot sections and cut each section lengthwise to form tracks rather than tunnels.

Cut string or cord into yard long pieces and if desired attach a paperclip or thin jump ring to one end so washers can be easily added.

potential energy and kinetic energy are noticed.

help to have these materials ready in a Ziploc bag.

## Doing the Activity

### Introduction:

Remind the students that energy is the ability to do work, and work is moving or changing.

Ask the students to provide some examples of things that need energy. (plants, animals, machines etc.)

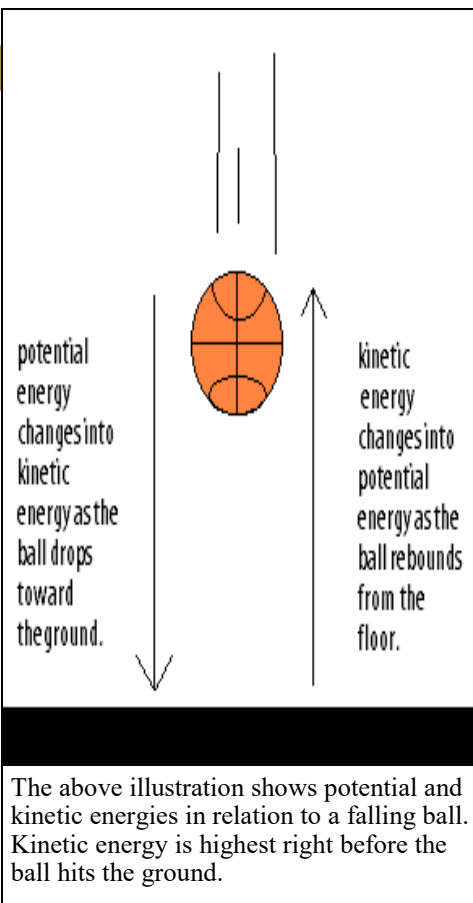
Ask whether things like rocks or playground swings have energy.

Explain that although some objects don't use electric, chemical, or solar energy they still have energy and can do work.

Explain to the students that if an object is moving, it is said to have kinetic energy. Objects that are not in motion but could move have potential energy.

Demonstrate with a ball. Hold the ball at shoulder height off the ground. Tell the students that at this point the ball has only potential energy. Drop the ball.

Explain that as the ball falls, the potential energy is gradually turned into kinetic energy. At the moment the ball hits the floor, it has only kinetic energy. As it bounces, the potential energy is recreated. In each group of 3-4 students, hand out a ball so that the students are able to recreate the demonstration. Have them say out loud the points where



Tell students that this shows the law of conservation of energy which states that energy can never be created or destroyed, it just changes forms.

### Activity 1: Swing

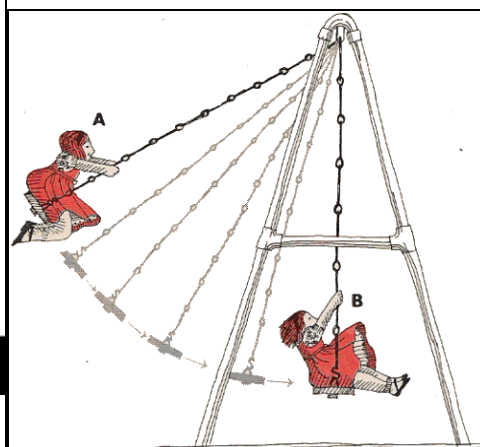
Ask the students how we can tell that the amount of energy doesn't change. (Ball bounces back to *about* the same height; effected by air resistance.)

Tell the students that they are going to test whether energy is also conserved on the swing set.

Divide the class into groups of 3-4 and give each group a string, washers, and a ruler. It may

Ask the students to create a pendulum by attaching one end of the string to one or more washers and taping the other end to the table's edge.

The students should fill in the worksheet on page 5



At A, that point of momentary motionlessness just before the downward plunge, she has only potential energy. As she starts down she develops kinetic energy. Halfway through the cycle, at B, her energy becomes completely kinetic, then gradually changes back to potential as the swing rises again

Ask the students to pull their pendulum back and measure 4 inches away from the pendulum's starting point (where it sits when hanging from the table top).

Have the students let the pendulum go and determine

A) How many times it swings back and forth in 10 seconds

Ask the students to record their results and repeat their

experiment with a different number of washers from different heights as instructed on worksheet.

Remind the class that to get the best results scientists try to only change one variable at a time.

Bring the class back together to discuss results.

Ask the class to mark on the worksheet where the pendulum has the most potential energy and the most kinetic energy. (At the very top and very bottom of the swing.)

Ask the students if changing the weight or length of the pendulum made it swing higher? How about faster?

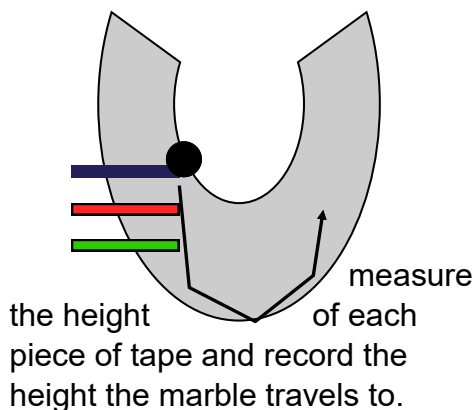
### Activity 2: Coaster Fun

Tell the students that there are more exciting ways to use potential energy than on the swing set... roller coasters!

Give each group of 3-4 a marble, ruler, tooth picks, tape as needed and a section of pipe insulation.

Let the students take 3-5 minutes to freely explore how to set up a roller coaster successfully. Clearly state expectations and give advice if needed. Review materials, restate the goal, and begin.

Each group's goal is to set up their roller coaster as directed (show students if needed) and observe if energy is being conserved. Students are to



the height of each piece of tape and record the height the marble travels to.

Have the students place a marble in the track so that it rolls down the hill and measure the distance it rolls up the other side.

Ask the students to repeat the experiment three times for each colored strip of tape. Students may use a tooth pick to mark the height the marble rolled to.

Compare the results of each experiment as a class and discuss whether energy is conserved in each case.

Discuss any factors that may have led to the marble not traveling exact same distance (friction, and air resistance).

### Conclusion

Ask how marble coaster reinforces law of conservation of

energy? (when marble rolls up a hill it loses  $K_e$  and slows down, but gains  $P_e$  because it is gaining height).

### Assessment

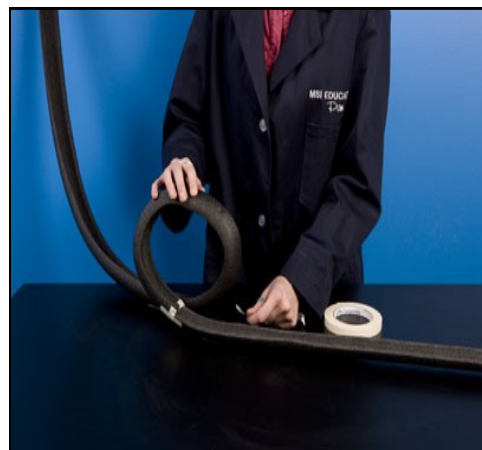
Ask students to name objects that use these concepts (bungee jumping, swing set, roller coaster, etc...).

Review the terms potential and kinetic energy.

Ask students why you can't swing over the bar on the swing set and the first hill of a roller coaster is always the biggest.

### Extensions

Have the students create a bigger roller coaster with multiple hills and a loop.



This photo shows a marble roller coaster

Have students come up with examples of potential energy and its counterpart in kinetic energy. ( $P_e$ : water held in a dam,  $K_e$ : water flowing over spillway.  $P_e$ : gasoline,  $K_e$ : burning gasoline used to power a car, etc)

Take students outside and test the concept of kinetic and potential energy on a swing set. Allow students to set up the experiment and record their results.

## Vocabulary

**Kinetic energy**-The energy attributed to something in motion. Calculated using the equation  $K = \frac{1}{2} mv^2$  where  $m$ =mass and  $v$ =velocity

**Potential energy**-the ability of a system to do work due to its position or internal structure. Gravitational potential energy is calculated using the equation  $P = mgh$  where  $m$ =mass  $h$ =height above the ground, and  $g=9.81\text{m/s}^2$  (acceleration due to gravity)

## Sources

“American Eagle” Image retrieved from: <http://frankprager.net/coaster39b.jpg>

“American Eagle” *Six Flags Great America* [http://www.sixflags.com/greatAmerica/rides/American\\_Eagle.aspx](http://www.sixflags.com/greatAmerica/rides/American_Eagle.aspx)

“Animal Speeds” <http://www.factmonster.com/ipka/A0004737.html>

“Kinetic Energy” <http://hyperphysics.phy-astr.gsu.edu/hbase/ke.html>

“Potential Energy” <http://physics.about.com/od/glossary/g/potentialenergy.htm>

“Swing” <http://www.comparestoreprices.co.uk/images/ju/jungle-gym-swing-module.jpg>

Swing Illustration <http://www.robinsonlibrary.com/technology/mechanical/machines/kinetic.htm>

Basketball Illustration <http://mrfizzix.com/basketball/dribbling.htm>

Pendulum Illustration [http://www.edinformatics.com/math\\_science/science\\_tests/scipop8\\_2011a.htm](http://www.edinformatics.com/math_science/science_tests/scipop8_2011a.htm)

<http://www.water.me.vccs.edu>

Name \_\_\_\_\_

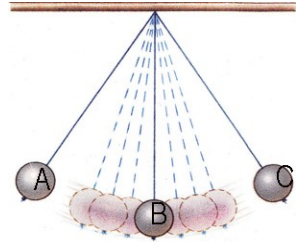
Create a pendulum by attaching a washer to one end of the string and taping the other end to the table top. Complete the table below by filling in your observations.

How many times does the pendulum swing back and forth in 10 seconds?

**AFTER** completing the table, answer the following questions using the picture as a guide.

At what point (A, B or C) does the pendulum have the most **Potential** Energy? \_\_\_\_\_ The most **Kinetic** Energy? \_\_\_\_\_

How do the washers effect the number of swings?



Starting Height	# of swings with 1 washer In 10 seconds	# of swings with 2 washers In 10 seconds	# of swings with 3 washers In 10 seconds
4 Inches			
8 Inches			
12 Inches			

Name \_\_\_\_\_

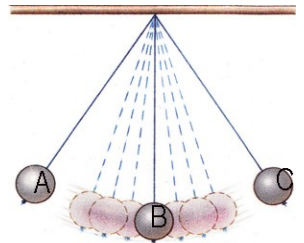
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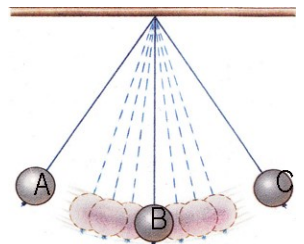
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Name \_\_\_\_\_

Create a marble coaster with the provided supplies. Measure the distance from each piece of tape to the ground. Record in table. Place the marble in the track at a tape mark and record the distance traveled. Complete three trials for each colored piece of tape. Record in table.

Draw a side view of your coaster . Label on your drawing where Potential energy ( $P_e$  ) occurs and where Kinetic energy ( $K_e$  ) occurs.

1)What do you notice about the distance the marble travels? Why do you think that happens?

	Distance marble traveled (1st Trial)	Distance marble traveled (2nd Trial)	Distance marble traveled (3rd Trial)
Height of pink tape _____			
Height of blue tape _____			
Height of yellow tape _____			

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